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SHEAR FREQUENCIES IN THE UPPER TROPOSPHERE AND LOWER STRATOSPHERE OVER ENGLAND

By J. K. BANNON, B.A.

In connexion with an investigation of turbulence as affecting aircraft it was necessary to evaluate the frequencies of occurrence over England of various ranges of shear both in the vertical and in the horizontal and also the Richardson number associated with the former. The frequencies of various shears and Richardson numbers occurring just above the tropopause were also investigated. These statistics are presented here, without discussion, in the hope that they may be of use in other connexions. It should be noted that occasions of very strong winds are not properly represented above 20,000 ft. (450 mb. approximately); wind observations are restricted in altitude when winds are strong because of the limited range of the observing radar set.

Shear in the vertical.—Table I(a) gives the percentage frequency of occurrence of various ranges of the shear in the vertical, $|\partial \mathbf{V}/\partial z|$, for the 450-mb., 300-mb. and 200-mb. levels ($\mathbf{V}$ is the horizontal wind vector and z is the height measured upwards). The observations made at Larkhill, given to the nearest degree in direction and the nearest knot in speed, were used to compute these shears. One month from each season was examined, *viz.* October 1946, January, April and June 1947; June was chosen in preference to July as there were more observations available for the former month. It is obvious that there is considerable variation in the frequencies from month to month. It is not claimed that any of these months is typical of its particular season.

Table I(b) gives the percentage frequencies of various ranges of shears for the upper troposphere (*i.e.* for the 450-mb. level and the 300-mb. and 200-mb. levels when appropriate) and for the lower stratosphere (*i.e.* for the 300-mb. and 200-mb. levels when they were above the tropopause) for the same months as in Table I(a).

Richardson number.—Table II(a) gives the percentage frequency of occurrence of various ranges of $\log_{10}$(Richardson number) for the same

observations for Larkhill from which Table I was derived. The Richardson number* is defined as

$$R_i = \frac{g}{T} \frac{\left(\frac{\partial T}{\partial z} + \Gamma\right)}{\left(\frac{\partial \mathbf{V}}{\partial z}\right)^2}$$

where T=temperature (absolute) and Γ=adiabatic lapse rate of temperature with height. As R_i ranged from very small values to over 1,000, $\log_{10} R_i$ was used in the analysis.

Table II(b) gives similar frequencies for the upper troposphere (450 mb. and above) and lower stratosphere (200 mb. and below).

TABLE I—PERCENTAGE FREQUENCY OF OCCURRENCE OF VARIOUS RANGES OF $|\partial \mathbf{V}/\partial z|$ AT LARKHILL

	Shear (kt./1,000 ft.) 0–2	2–4	4–6	6–8	8–10	10–12	12–14	No. of obs.	Mean shear
	percentage frequency								kt./1,000 ft.
				(*a*)					
200-mb. level									
October 1946	53·8	31·1	12·3	2·8	..	..	..	106	2·36
January 1947	47·0	28·9	12·1	6·0	4·8	..	1·2	83	2·91
April 1947	61·8	26·4	8·8	1·5	..	1·5	..	68	2·11
June 1947	51·7	24·2	18·4	5·7	..	..	..	87	2·53
Total 4 Seasons	53·1	27·9	13·1	4·1	1·2	0·3	0·3	344	2·48
300-mb. level									
October 1946	65·8	26·3	6·1	1·8	..	..	..	114	1·83
January 1947	52·5	35·6	6·9	4·0	1·0	..	..	101	2·26
April 1947	57·0	30·2	12·8	..	..	..	..	86	2·06
June 1947	62·5	32·7	4·8	..	..	..	..	104	1·73
Total 4 Seasons	59·8	31·1	7·4	1·5	0·2	..	..	405	1·96
450-mb. level									
October 1946	63·6	29·7	4·2	2·5	..	..	..	118	1·92
January 1947	45·0	35·9	8·3	6·7	3·3	0·8	..	120	2·76
April 1947	58·5	33·1	4·7	2·8	0·9	..	..	106	2·11
June 1947	59·7	33·3	6·1	..	0·9	..	..	114	1·91
Total 4 Seasons	56·7	33·0	5·9	3·1	1·3	0·2	..	458	2·18
				(*b*)					
Stratosphere (200-mb. level and below)									
October 1946	51·5	29·4	14·7	4·4	..	..	..	68	2·53
January 1947	46·4	29·6	9·9	7·1	5·6	..	1·4	71	3·03
April 1947	59·6	28·6	7·2	2·3	..	2·3	..	42	2·31
June 1947	50·0	22·0	20·0	8·0	..	..	..	50	2·79
Total 4 Seasons	51·1	27·8	13·0	5·6	1·7	0·4	0·4	231	2·73
Troposphere (450-mb. level and above)									
October 1946	64·4	28·4	5·3	1·9	..	..	..	264	1·86
January 1947	49·1	34·5	8·2	5·5	2·3	0·4	..	220	2·51
April 1947	59·4	30·2	8·5	1·4	0·5	..	..	212	2·03
June 1947	60·7	31·7	6·8	0·4	0·4	..	..	249	1·85
Total 4 Seasons	58·8	31·1	7·1	2·2	0·7	0·1	..	945	2·05

Shear and Richardson number at or just above the tropopause.—Wind observations at Larkhill for the month of February 1948 were re-plotted in the neighbourhood of the tropopause, and the winds computed over 1-min. intervals instead of 3-min. intervals as is the normal practice. From these re-computed winds it was possible to derive more accurate wind gradients than from the observations made at standard levels several thousand feet apart. Shears at two levels were investigated, (i) the shear between the wind during the minute in which the tropopause was reached and the wind in the following

*RICHARDSON, L. F.; The supply of energy from and to atmospheric eddies. *Proc. roy. Soc. London*, A, **97**, 1920, p. 354.

minute; and (ii) the shear between the winds observed in the first and second complete minutes of observations, respectively, within the stratosphere. (i) gives an estimate of the shear immediately above the tropopause or partly across it; (ii) gives the shear just above the tropopause in a layer about 1,200 ft. above the layer considered in (i).

TABLE II—PERCENTAGE FREQUENCY OF OCCURRENCE OF VARIOUS RANGES OF $\log_{10} R_i$; LARKHILL

	Log₁₀ Ri: −1·0 to −0·5	−0·5 to 0·0	0·0 to 0·5	0·5 to 1·0	1·0 to 1·5	1·5 to 2·0	2·0 to 2·5	2·5 to 3·0	3·0 and above	No. of obs.	Mean $\log_{10} R_i$
	percentage frequency										
					(a)						
200-mb. level											
October 1946	..	..	3·0	18·0	32·0	32·0	10·0	4·0	1·0	100	1·41
January 1947	..	1·3	7·9	18·4	32·9	22·4	10·5	6·6	..	76	1·38
April 1947	..	..	8·2	14·8	26·2	26·2	16·4	6·6	1·6	61	1·53
June 1947	..	..	10·7	26·2	21·5	22·6	10·7	8·3	..	84	1·32
Total 4 Seasons	..	0·3	7·2	19·6	28·3	26·2	11·5	6·2	0·6	321	1·40
300-mb. level											
October 1946	..	..	12·4	23·0	32·7	22·1	6·2	2·7	0·9	113	1·23
January 1947	1·1	2·1	9·7	28·1	25·8	22·6	3·2	2·1	4·3	93	1·22
April 1947	..	..	18·8	24·7	24·7	20·0	5·9	2·4	3·5	85	1·22
June 1947	..	2·0	10·8	29·4	20·5	14·7	19·6	2·0	1·0	102	1·26
Total 4 Seasons	0·3	1·0	12·7	26·5	26·2	19·8	8·9	2·3	2·3	393	1·24
450-mb. level											
October 1946	0·8	2·5	11·0	26·3	32·3	17·0	6·8	1·7	1·6	118	1·18
January 1947	0·8	4·2	18·3	25·8	29·2	17·5	2·5	1·7	..	120	1·00
April 1947	..	0·9	9·4	35·9	29·2	12·3	8·5	3·8	..	106	1·19
June 1947	..	2·6	6·1	29·9	27·2	22·8	7·9	2·6	0·9	114	1·26
Total 4 Seasons	0·4	2·6	11·4	29·3	29·5	17·5	6·3	2·4	0·6	458	1·11
					(b)						
Stratosphere (200-mb. level and below)											
October 1946	..	..	1·5	19·4	28·3	34·3	9·0	6·0	1·5	67	1·42
January 1947	..	1·4	8·3	18·1	29·2	23·6	12·5	6·9	..	72	1·40
April 1947	..	..	7·3	12·2	24·4	24·4	19·5	9·8	2·4	41	1·64
June 1947	..	..	7·8	27·5	19·6	19·6	13·7	9·8	2·0	51	1·47
Total 4 Seasons	..	0·4	6·1	19·4	26·0	26·0	13·0	7·8	1·3	231	1·46
Troposphere (450-mb. level and above)											
October 1946	0·4	1·1	11·0	23·5	33·3	20·4	7·2	1·9	1·2	264	1·23
January 1947	0·9	3·2	14·3	27·2	29·0	19·4	2·3	1·8	1·9	217	1·09
April 1947	..	0·5	13·3	29·8	27·5	17·1	7·6	2·8	1·4	211	1·21
June 1947	..	2·0	9·2	28·9	24·1	20·1	12·5	2·8	0·4	249	1·24
Total 4 Seasons	0·3	1·7	11·8	27·2	28·6	19·4	7·6	2·3	1·1	941	1·20

TABLE III—PERCENTAGE FREQUENCY OF VARIOUS RANGES OF $|\partial \mathbf{V}/\partial z|$ IN THE LOWER STRATOSPHERE AND NEAR THE TROPOPAUSE; LARKHILL

Level	Shear (kt./1,000 ft.): 0–2	2–4	4–6	6–8	8–10	10–12	12–14	14–16	No. of obs.	Mean shear
	percentage frequency									kt./1,000 ft.
(i) Just above or at tropopause*	15·1	48·8	20·9	9·3	2·3	3·5	..	..	86	3·81
(ii) Lower stratosphere*	28·2	43·5	10·6	7·1	7·1	1·2	1·2	1·2	85	3·65
(iii) At 300-mb. and 200-mb. levels†	50·0	32·7	9·2	4·9	2·7	..	0·5	..	184	2·55

* February 1948 † January 1947

Table III gives the percentage frequencies of occurrence of various ranges of $|\partial \mathbf{V}/\partial z|$ for cases (i) and (ii) respectively; for comparison, similar frequencies for the 300-mb. and 200-mb. levels together for the month of January 1947 are given in the same table. The months January 1947 and February 1948 both had periods of disturbed and anticyclonic weather and were thus not dissimilar.

TABLE IV—PERCENTAGE FREQUENCY OF OCCURRENCE OF VARIOUS RANGES OF $\log_{10} R_i$ IN THE LOWER STRATOSPHERE AND NEAR THE TROPOPAUSE; LARKHILL

Level	$\log_{10} Ri$: −1·0 to −0·5	−0·5 to 0·0	0·0 to 0·5	0·5 to 1·0	1·0 to 1·5	1·5 to 2·0	2·0 to 2·5	2·5 to 3·0	3·0 and above	No. of obs.	Mean $\log_{10} Ri$
	percentage frequency										
(i) Just above or at tropopause*	..	..	9·3	24·4	39·5	20·9	4·7	1·2	..	86	1·19
(ii) Lower stratosphere*	..	2·4	11·8	18·8	30·6	24·7	5·9	3·5	2·[illegible]	85	1·30
(iii) At 300-mb. and 200-mb. levels†	0·6	1·8	8·9	24·2	29·0	22·5	6·5	4·1	2·[illegible]	169	1·29

*February 1948; †January 1947

TABLE V—PERCENTAGE FREQUENCY OF OCCURRENCE OF VARIOUS RANGES OF HORIZONTAL SHEAR OVER THE MIDLANDS (REGARDLESS OF SIGN)

	Horizontal shear (hr.$^{-1}$): 0·00 to 0·05	0·05 to 0·10	0·10 to 0·15	0·15 to 0·20	0·20 to 0·25	0·25 to 0·30	0·30 to 0·35	0·35 to 0·40	0·40 and above	No. of obs.	Mean shear
	percentage frequency										hr.$^{-1}$
					(a)						
200-mb. level											
October 1946	51·1	24·5	6·1	6·1	2·0	6·1	4·1	..	..	49	0·088
January 1947	60·9	15·2	8·7	4·3	..	6·5	2·2	2·2	..	46	0·071
April 1947	47·3	29·0	15·8	5·3	..	..	2·6	..	..	38	0·065
June 1947	48·4	27·3	12·1	6·1	..	..	..	6·1	..	33	0·074
Total 4 Seasons	52·5	23·5	10·2	5·4	1·2	3·6	2·4	1·2	..	166	0·075
300-mb. level											
October 1946	33·8	32·4	17·6	8·8	4·4	1·5	..	..	1·5	68	0·081
January 1947	31·2	40·2	15·6	6·5	2·6	..	..	..	3·9	77	0·087
April 1947	51·6	21·6	16·7	3·3	1·7	1·7	1·7	..	1·7	60	0·073
June 1947	26·7	37·5	17·9	12·5	..	1·8	1·8	1·8	..	56	0·092
Total 4 Seasons	35·7	33·3	16·9	7·7	2·3	1·1	0·7	..	1·9	261	0·083
450-mb. level											
October 1946	52·4	19·0	11·9	7·1	3·6	..	2·4	2·4	1·2	84	0·071
January 1947	40·9	34·4	12·9	6·4	3·2	1·1	..	..	1·1	93	0·072
April 1947	37·1	30·4	15·7	5·6	3·4	4·5	1·1	2·2	..	89	0·067
June 1947	41·3	36·0	16·0	6·7	..	..	..	..	..	75	0·063
Total 4 Seasons	42·8	29·9	14·1	6·4	2·6	1·5	0·9	1·2	0·6	341	0·074
					(b)						
Stratosphere (200-mb. level and below)											
October 1946	69·3	19·2	3·8	..	..	7·7	..	..	..	26	0·050
January 1947	58·0	22·0	10·0	2·0	..	4·0	2·0	2·0	..	50	0·065
April 1947	61·3	22·6	16·1	..	..	..	..	..	..	31	[illegible]
June 1947	50·0	12·5	12·5	16·6	4·2	..	..	4·2	..	24	[illegible]
Total 4 Seasons	59·5	19·8	10·7	3·8	0·8	3·1	0·8	1·5	..	131	0·065
Troposphere (450-mb. level and above)											
October 1946	42·4	25·7	13·7	8·6	4·0	1·1	2·3	1·1	1·1	175	[illegible]
January 1947	36·8	35·5	13·9	7·2	3·0	1·2	..	..	2·4	166	[illegible]
April 1947	40·4	28·2	16·0	5·8	2·6	3·2	1·9	1·3	0·6	156	[illegible]
June 1947	35·8	38·6	16·4	7·1	..	0·7	0·7	0·7	..	140	0·072
Total 4 Seasons	39·0	31·7	14·9	7·2	2·5	1·5	1·3	0·8	1·1	637	[illegible]

Table IV gives similar frequencies of $\log_{10} R_i$ for the layers (i) and (ii) and also for the 300-mb. and 200-mb. levels together. It will be noted that the character of all three frequencies is similar.

Horizontal shear.—The shear in the horizontal may be defined as

$$\partial \mathbf{V}/\partial n - \mathbf{V}/r$$

where n is the horizontal direction at right angles to $\mathbf{V}$ and to its right, and r is the radius of curvature (positive for cyclonic motion) of the stream-line

Table V(a) gives the percentage frequencies of occurrence of various ranges of the horizontal shear (regardless of sign) over the Midlands for the months October 1946, January, April and June 1947, for the 450-mb., 300-mb. and 200-mb. levels. The wind observations at Larkhill, Downham Market and Liverpool were used for this computation. Owing to the difficulty of estimating the curvature of the stream-lines no great accuracy can be claimed for a particular observation of horizontal shear; however, taken all together, the observations probably give a good idea of the true frequency distribution.

Table V(b) presents similar frequencies for the upper troposphere (450 mb. and above) and lower stratosphere (200 mb. and below). As in the frequencies given in Tables I and II there is considerable variation between the several months which may or may not illustrate the true seasonal variation.

SEA BREEZE ACROSS LONDON

By W. A. L. MARSHALL

A very good example of what appears to have been a sea breeze spreading across London to Hampshire and Berkshire from the Thames Estuary occurred on July 1, 1949.

During the early afternoon the wind recorded by an anemometer on the roof of the Meteorological Office, Kingsway, had been NE. 6 kt., with fluctuations of speed and direction typical of a quiet summer day. The wind veered to E. at 1550 G.M.T., increased quickly to double its former strength at 1605 G.M.T., and continued as a fresh breeze with gusts of 20–23 kt. throughout the evening. Temperature fell sharply with the onset of the sea breeze and relative humidity rose by 17 per cent.

The resulting cool interlude in an existing warm spell was the subject of much comment in London. Values of the " cooling power "* of the air based on Kingsway readings of wind speed and temperature give only an incomplete indication of human reactions in the suburbs. Nevertheless, Table I serves as a convenient method of comparing the coolness of July 1 with the warmth of the previous evening. The 2nd and 3rd columns are broadly applicable to a person in summer clothes relaxing in the garden, while the 4th and 5th columns have their lesson for the very energetic who wish to avoid chills after their exertion. The marked drop in cooling power of the air between 1800, and 2100 on June 30 was due to the wind falling off from 6 m.p.h. to calm.

TABLE I—COOLING POWER OF THE AIR OVER CENTRAL LONDON FOR SURFACES AT A TEMPERATURE OF 98°F.

Time	For a dry surface June 30	July 1	For a wet surface June 30	July 1
G.M.T.	*millicalories per square centimetre per second*			
1500	12 (pleasant)	15 (pleasant)	49	53
1800	10 (warm)	27 (cool)	45	69
2100	4 (very warm)	29 (cool)	<20	69

The time of occurrence of sudden changes of wind, temperature and relative humidity at meteorological observing stations in the Thames Valley on July 1, 1949, and the amount of change in the following hour, is summarised in Table II.

*GOLD, E.; The effect of wind, temperature, humidity and sunshine on the loss of heat of a body at temperature 98°F. *Quart. J. R. met. Soc., London*, **61**, 1935, p. 316.

TABLE II—CHANGES OF WIND, TEMPERATURE AND RELATIVE HUMIDITY, JULY 1, 1949

Place	Time of change	Wind					Temperature		Relative Humidity	
		Before onset		After onset		Highest gust	Before onset	Change	Before onset	Change
	G.M.T.	°true	kt.	°true	kt.	kt.	°F.	°F.	%	%
Shoeburyness	1130	080	1	130	7	8	64	−1	56	+9
West Malling	(1530)	060	7	060	14	*	75	−5	46	+14
Biggin Hill	(1550)	030	2	060	10	*	76	−7	40	+22
Kingsway	1605	030	6	090	12	23	76	−4	46	+17
Croydon	1610	030	4	060	10	18	78	−5	38	+22
Kew Observatory	1640	050	6	100	15	22	77	−5	37	+21
Hendon	(1650)	050	6	100	8	*	77	−5	35	+24
Northolt	1725	040	10	100	13	*	77	−6	36	+21
London Airport	1730	030	6	080	15	20	79	−8	34	+20
S. Farnborough	1810	070	3	120	9	20	77	−8	40	+28
Benson	(1950)	(360)	6	(060)	10	*	..	..	..	..
Abingdon	2040	060	4	100	8	16	..	..	..	..

Entries in brackets are approximate.

* = No self-recording anemograph.

Wind, temperature and relative-humidity changes shown in the tracings of autographic records in Fig. 1 indicate that the sea breeze moved across London and thence to South Farnborough at the mean speed of the easterly wind. The difference in wind turbulence before and after its onset is noteworthy. It then seems to have flowed through the gap between the Chilterns and the White Horse Hills to the north-west of Reading, reaching Abingdon with sufficient vigour to overcome a local NE. wind of appreciable strength which had been noted as having occurred there fairly regularly each evening during the fine spell.

The main sea breeze, which reached West Malling through the Medway Valley at 1530 G.M.T., was preceded by similar though less pronounced weather changes about two hours earlier. These may have been caused by a minor sea breeze from the Chatham area.

Smoke from London caused an abrupt temporary deterioration of visibility to 3–4 miles at Northolt and London Airport with the onset of the easterly wind. The sky, which had previously been clear apart from small amounts of fine-weather cumulus, became about three-quarters covered with strato-cumulus clouds for a time.

The normal diurnal changes of temperature and relative humidity had been in progress for some hours before the sea breeze reached Benson and Abingdon. No significant change in the rate of temperature fall was obvious but the hygrograms show that relative humidity, which had been rising steadily at both places, fell temporarily at Benson and remained steady for an hour or so at Abingdon at the estimated times of arrival of the sea breeze.

Isochrones of the onset of the sea breeze are given in Fig. 2. The temperature lapse rate over south-east England on the afternoon of July 1 was superadiabatic from the surface to 3,750 ft. An anticyclone moved eastward across England during the day. The consequent veering of a light geostrophic wind from NE.

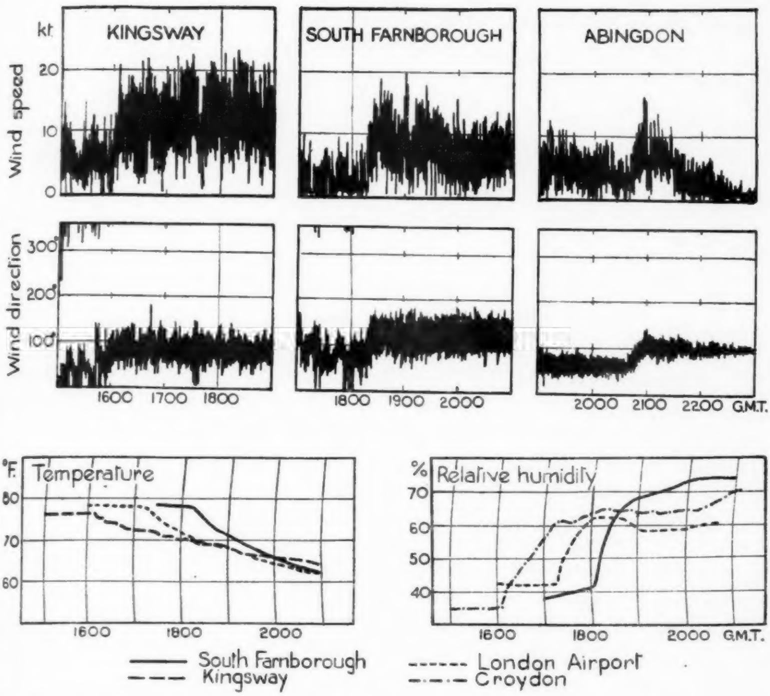

FIG. I—AUTOGRAPHIC RECORDS OF WIND, TEMPERATURE AND HUMIDITY, JULY 1, 1949

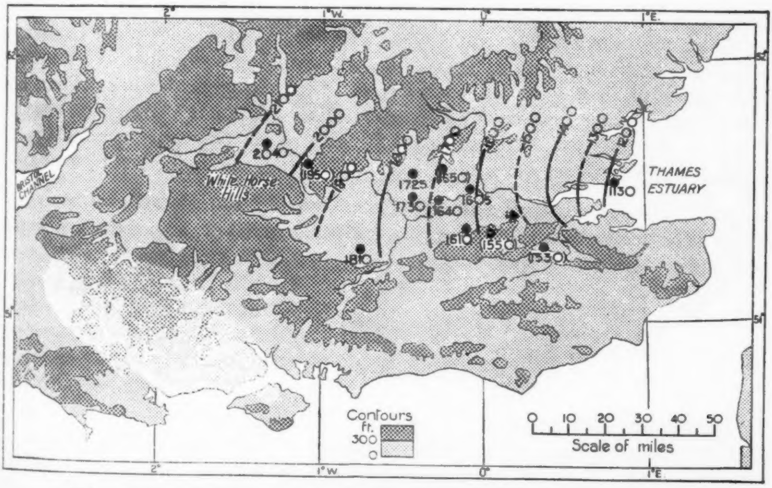

FIG. 2—ISOCHRONES OF ONSET OF SEA BREEZE, JULY 1, 1949

All times are G.M.T. Times in brackets are approximate

to ENE. probably contributed to the penetration of the sea breeze 100 miles inland. Upper winds were as follows:—

Height	Downham Market						Larkhill					
	0900		1500		2100		0900		1500		2100	
	°true	kt.	°true	kt.	°true	kt.	°true	kt.	°true	kt.	°true	kt.
Surface	360	8	030	10	080	8	360	15	349	12	230	3
1000 mb.	360	8	030	10	085	15						
900 mb.	340	7	022	7	079	10	356	13	009	10	065	10
700 mb.	334	4	359	3	011	4	327	11	006	5	103	10

METEOROLOGY AT HEARD AND MACQUARIE ISLANDS

By W. J. GIBBS

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The Australian National Antarctic Research Expedition established stations at Heard Island in December 1947 and at Macquarie Island in April 1948. Included in the members of the two parties were the following meteorological personnel:—

Heard Island

Mr. A. V. Gotley (Meteorologist)
Mr. A. T. Carroll (Observer)
Mr. K. W. York (Observer)

Macquarie Island

Mr. A. Martin (Meteorologist)
Mr. R. Chadder (Observer)
Mr. B. Monkhouse (Observer)

These men are all members of the Meteorological Branch, Department of Interior, which, in addition to making available their services to the Australian National Antarctic Research Expedition, also provided the necessary meteorological equipment. Both Mr. Gotley and Mr. Martin were placed in charge of the party on their respective islands, which added a considerable burden of responsibility to a very full programme of meteorological work. They both rendered sterling service to the Australian National Antarctic Research Expedition and the Meteorological Branch, and were ably assisted by the Meteorological Observers under their control (see photos between pp. 174-5).

In February and April 1949 relief parties arrived at Heard and Macquarie Islands respectively, and the meteorological personnel of those parties at present serving on the islands are:—

Heard Island

Mr. A. Garriock (Meteorologist)
Mr. R. G. Smith (Observer)
Mr. O. E. Warden (Observer)

Macquarie Island

Mr. N. Robertson (Meteorologist)
Mr. L. Behn (Observer)
Mr. W. Denham (Observer)

Continuity of observations was maintained during the "change over" and the present parties are maintaining the high standard set by the pioneer teams.

Geography.—The geographical co-ordinates and heights of the islands are:—

Heard Island—53°01'S., 73°23'E., 16 ft. above M.S.L.

Macquarie Island—54°30'S., 158°57'E., 20 ft. above M.S.L.

Heard Island is thus approximately 2,000 nautical miles and Macquarie Island 800 nautical miles from the nearest point on the Australian coastline.

Heard Island is roughly circular in shape and about 15 miles across. The terrain rises sharply from the coastline to a central dome at about 8,000 ft. in the centre of which a volcanic peak, Big Ben, rises to a height of 9,000 ft. Snow completely covers the island in winter but in summer the snow-line rises to about 500 ft.

Macquarie Island is about 18 miles in length and from 2 to 5 miles wide. Most of the island consists of a plateau about 1,000 ft. in height. In midwinter snow lies permanently on the plateau and occasionally covers the lower ground, but in the summer no part of the island is permanently snow covered.

Establishment.—Before the meteorological and other scientific activities of the parties could commence, it was necessary to erect living quarters and install scientific apparatus and radio equipment. This entailed the unloading of the expedition ship and the erection of camps sufficiently robust to withstand the winds of gale force which blow on these islands. Equipment for routine meteorological observations, both of conditions at the surface and in the upper air, had to be installed so as to work in rigorous conditions which were unfamiliar to the personnel operating it. In addition to their routine meteorological tasks the meteorologists shared in the work of building and maintaining the camp sites.

Observations.—At three-hourly intervals observations are made of pressure, dry- and wet-bulb temperature, surface wind speed and direction, and weather and cloud conditions. Once daily a radio-sonde ascent provides pressure, temperature and humidity data to a height of about 55,000 ft. When cloud conditions are suitable, pilot-balloon observations of upper winds are made four times daily. The results of these observations are transmitted with the minimum delay possible by radio to Australia where they are circulated to certain offices of the Meteorological Branch and included in the regular meteorological W/T broadcasts of Australian data.

Results.—There are two main results which are forthcoming from these observations. The first is the accumulation of meteorological data for the two islands. Observations were made at Macquarie Island during the years 1911–14 but only fragmentary data were available previously for Heard Island. When published, this data will be a significant contribution to the mass of observational material available for meteorological research. The second result is the appreciation of the usefulness of the reports in the analysis of the structure of the atmosphere in the Australian region and their contribution to the problem of forecasting in that region.

Since the receipt of the first radio reports from Heard and Macquarie Islands in Australia, efforts have been made to co-ordinate them with the results of observations made in Australia. More experience will be necessary before final conclusions will be possible, but it is the firm impression of meteorologists

engaged in using the reports that a general picture of the air circulation over the ocean to the south of Australia is possible. The work of the late Sir Edward Kidson*† on the meteorology of the Southern Ocean, together with the meteorological results of earlier Antarctic expeditions, provides a useful basis for the present investigations, but the study of meteorology has made such rapid strides during the past ten years that most of the current work is of a more advanced nature than the former investigations.

Synoptic analyses of the data are carried out at Heard and Macquarie Islands, in the Analysis and Development Section, Central Meteorological Bureau, and by Deputy Directors in the States. There has been considerable correspondence between the Deputy Directors and Central Meteorological Bureau on the subject, in addition to which articles on synoptic analysis by Langford and Gibbs have appeared in the *Weather Development and Research Bulletin.* At present a comprehensive report on the first year's operation of the meteorological stations at Heard and Macquarie Islands is being prepared and it is hoped that this, together with the data and analysed charts will be published as soon as possible after completion.

Tentative conclusions after a year's experience in analysing the data may be summarised as follows:—

Using all available reports, it is possible to locate fairly accurately the major pressure systems over the Southern Ocean; the great depressions of the Southern Ocean appear to follow two main tracks, the first from Marion Island to Heard Island and thence towards the east or south-east, the second from the southern coastline of Australia to the vicinity of Macquarie Island and then mainly to the south-east. The great depressions of the Southern Ocean have a definite influence on pressure patterns and, therefore, weather over Australia. This means that Southern Ocean analysis is of assistance in short-period forecasting in Australia and may greatly assist the preparation of extended period forecasts.

RADAR WEATHER ECHOES

By R. F. JONES, B.A.

Part III

Occlusion by Radar.—As may, perhaps, be expected, the radar picture of the occlusion shows some of the features of both warm and cold fronts which have already been described.

The picture of the occlusion, as seen on the P.P.I., suggests that quite frequently the structure is as simple as the charts suggest with a single belt of precipitation often visible to ranges of 40 miles or more (see photograph (*a*) of series of photographs between pp. 174–5). The rain belt is wider than that accompanying a cold front but less extensive than that associated with an active warm front. The surface position of the front is usually clearly marked by the termination of the echo at a well defined edge. Unlike the cold-front echo, however, this well defined edge only rarely gives signs of isolated cores of high intensity, and the impression given is that although the up currents are larger at this edge than in the normal warm front they are nevertheless wide-spread and fairly

*KIDSON, E.; Discussion of observations at Adélie Land, Queen Mary Land and Macquarie Island. Australasian Antarctic Expedition 1911–14. Scientific Reports, Series B, Vol. VI Meteorology. Sydney, 1946.

†KIDSON, E.; Daily weather charts extending from Australia and New Zealand to the Antarctic Continent. Australasian Antarctic Expedition 1911–14. Scientific Reports, Series B, Vol. VII Meteorology. Sydney, 1947.

uniform in strength, *i.e.* cumulonimbus development is much less frequent in the straightforward occlusion than in the cold front.

Occasionally the structure indicated is considerably more complex than in the case outlined above with a much more extensive area of precipitation and the appearance of more or less parallel lines of higher echo intensity (and hence almost certainly higher rainfall intensity) within the general echo, and also, on some occasions, signs of isolated cores of echo suggesting cumulonimbus activity (see photograph (*b*)).

Radar on such occasions can give a much finer picture of the precipitation associated with the front than can possibly be obtained from even detailed weather charts, and may therefore be of considerable assistance in determining the detailed structure of the front. This possibility is further demonstrated on those occasions when the warm sector has already become so narrow that it is impossible to distinguish on the charts the warm front from the cold front, with the result that the front is drawn as already occluded. Such an occasion is shown in photograph (*c*).

In the vertical cross-section the type of echo is usually more akin to that from the warm front than from the cold front in that a bright band is usually visible about the height of the freezing level (photographs (*d*) and (*e*)), although occasionally it may be interrupted by the appearance of a stronger column of echo. The echo is often more intense than the warm-front type, and it is noteworthy that more extensive echoes from above the bright band than for the warm front are usually to be seen which, although retaining their characteristic diffuse appearance, may exhibit some variations in intensity (photograph (*e*)). This greater vertical extent of the echo indicates that either the ice crystals are growing to a greater size above the freezing level in the occlusion than in the warm front or that aggregation of the ice crystals to form snow-flakes takes place at a greater height (or lower temperature). This has been interpreted* as an indication that the wide-spread vertical currents are stronger in the case of the occlusion than for the warm front, while the variations in intensity of the echo above the bright band indicate a somewhat less uniform value of these up currents. The up currents are, however, still relatively small compared with the isolated vertical currents which lead to cumulonimbus formation and the occurrence of clearly defined columns of weather echo. Such columns of echo do occur occasionally in the occlusion echo but with less frequency than in the cold-front cases.

In general it can be said that the radar evidence indicates that, while warm and cold fronts conform quite closely to the accepted ideas of the processes which produce the frontal rain, the occlusion processes are sometimes considerably more complex and not capable of being interpreted by a simple model of the frontal structure.

Further details of the photographic illustrations follow below :—

Photograph (*a*).—This P.P.I. photograph was taken at 1345 G.M.T. on September 10, 1948. The radial markers are at 20° intervals from magnetic north and the range circles are at 5-mile intervals, the outermost circle being at a range of 55 miles. The channels through the echo on approximate bearings of 30° and 50° are caused by local screening of the radio energy by trees. The

*JONES, R. F.; The heights and temperatures at the tops of radar echoes associated with various cloud systems. *Met. Res. Pap., London*, No. 458, 1949.

surface position of the front, *i.e.* the edge of the echo nearest to the station, is fairly well defined but without any clearly marked cores of higher intensity while the rain belt is seen to be wider than in the normal cold front.

Photograph (*b*).—This P.P.I. photograph was taken at 1511 G.M.T. on August 6, 1948. The precipitation pattern is clearly of a more complex nature than in photograph (*a*) with a tendency to bands of precipitation without clear-cut edges, but in the north-west and north stronger and more isolated echoes of higher intensity appear, indicating, it is thought, cumulonimbus development.

Photograph (*c*).—This photograph was taken at 1203 G.M.T. on December 13, 1948. Range and bearing markers are not shown on the photograph but the outer edge of the photograph corresponds to a range of about 65 miles while magnetic north is indicated by the bright radial line. It will be noted that from an area just north of the station the echo divides into two arms, one running south-south-east and the other south-south-west from this area. It is thought that the echo to the south-south-east and east of the station is from the warm front while that to the south-south-west, which is somewhat narrower, comes from the cold front. The complex echo to the north is associated with the occlusion. A narrow warm sector of this character is unlikely to be indicated clearly on synoptic charts.

Photograph (*d*).—This H.R.T. photograph was taken at 1337 G.M.T. on September 10, 1948, on a bearing of 76° magnetic and is therefore a cross-section at right angles to the front shown in photograph (*a*). As in photograph (*a*) the surface position of the front (nearest to the station) shows a clearly defined edge but without any evidence of column structure. The bright-band effect is to be seen at a height of 10,000 ft. but it is noteworthy that the echo extends with a diffuse character to a considerable height above the bright band. The effect of increase with height of the wind is clearly visible in the inclination of the edge of the echo above the bright band to the vertical. The effect is more marked above the bright band due to the lower terminal velocity of the snowflakes or ice crystals compared with that of the raindrops beneath the bright band.

Photograph (*e*).—This H.R.T. photograph was taken at 1129 G.M.T. on December 13, 1948, on a bearing of 349° magnetic and is therefore a vertical section on this bearing of the P.P.I. echo shown in photograph (*c*), at the time when the eastern arm of the echo was over the station. The broad bright band centred at about 6,000 ft. and extending 72 miles is clearly visible while the extensive echoes above the bright band show variations in intensity although still of a diffuse character without clear-cut edges and tops.

(*To be concluded*)

OFFICIAL PUBLICATIONS

A paper by Mr. T. H. Kirk, B.Sc., on the seasonal change of surface temperature of the North Atlantic Ocean has been approved for printing as a *Geophysical Memoir*.

Mr. Kirk has made a harmonic analysis of the seasonal change of surface temperature of the North Atlantic Ocean. The parameters of the harmonic series are presented in the paper on charts, and it is shown how they can be readily used to obtain a formula for the seasonal change at any point within

the area covered. Mr. Kirk also discusses the relative importance of the various factors affecting the seasonal change and provides a series of charts showing the rate of change of mean sea-surface temperature for each month of the year.

The following publication has recently been issued:—

PROFESSIONAL NOTES

No. 101—The climates of Addu Atoll, Agalega Islands and Tristan da Cunha. By E. V. Newnham, B.Sc.

This note summarises two or three years' observations on two tropical islands in the Indian Ocean and one in the South Atlantic.

On Addu Atoll (lat. 1°S.), the southernmost of the Maldive Islands, the predominant wind in January was northerly, but backed month by month through W. to between S. and SE. in July, veering gradually back to N. in later months. Rainfall averaged about 7 in. per month, without clear indication of wet and dry seasons, and monthly mean temperature ranged between 81°F. and 83°F.

On one of the Agalega Islands (lat. 11°S.) winds were observed to be variable in January and February, while the SE. trade wind prevailed in other months. Rainfall was very similar to that on Addu Atoll, but mean temperature was 82°F. from February to April and 78°F. in August and September.

Tristan da Cunha (lat. 11°S.), although not far south of the anticyclonic belt of the southern hemisphere, was found to experience winds and weather more appropriate to the "roaring forties" than to an anticyclone during most of the year. Observations on ships show that W. to NW. gales are frequent in this neighbourhood, especially in the southern winter, when Beaufort force 7 or more is reached on 10 to 14 days per month. The central mountain of Tristan causes local distortion of these winds, and made SW. the most frequent direction. Mean temperature was 52°F. in August and September, and nearly 65°F. in February. Rainfall averaged about 5 in. per month.

ROYAL METEOROLOGICAL SOCIETY

As most readers will know six symposia were held at Oxford during the last week in March as part of the Society's Centenary celebrations. We are publishing brief reports, three of which are given in this number, on these symposia.

March 29, 1950: The physics of clouds and precipitation. Chairman—Professor G. M. B. Dobson.

Dr. Dobson in his introductory remarks reviewed for a crowded audience recent laboratory work on the physics of clouds and precipitation with particular reference to the temperatures at which water-drops usually freeze and also to the properties of the various ice-forming nuclei which can initiate the direct deposition of ice from vapour in supersaturated conditions.

In the animated discussion which followed, in which it was pleasing to listen to such a strong representation from France, the results of much original work were made public for the first time.

M. Bricard and *Prof. Dessens* described their methods of obtaining water-drops for study. *M. Lafargue* reported that he had found that droplets of various solutions of radius less than 20 microns invariably froze at a temperature of

$-40 \pm 1{\cdot}5$°C., and that as the radius of the drops was increased the critical temperature of freezing rose to approach asymptotically a value dependent on the nature and concentration of the solution. The value of the absolute threshold temperature was suggestively similar to the temperature of -41°C. recently put forward in a number of quarters as that below which condensation never occurred; Dr. Schaefer (United States) whose name will always be associated with the artificial seeding of clouds (" Project Cirrus ") had, however, obtained for this temperature the value of $-38{\cdot}9$°C.

Mr. Mason described recent advances in the theory of crystal growth. Dendritic growth was due to local variations in the degree of supersaturation, but the growth of a crystal face where the degree of supersaturation was small and nearly constant over the face could not be explained in this way. F. C. Frank of Bristol[1]* had presented to the Faraday Conference of 1949 a theory of crystal growth based on the theory of " dislocations ", from which Mr. Mason had obtained results in the case of ice which seemed consistent with experience, *e.g.* a prism took 5 minutes to attain a length of 35 microns at a temperature of -35°C. He thought that dendritic growth was confined to relatively high temperatures.

No discussion of the physics of clouds and precipitation would be complete without reference to the electrical aspect. *M. Queney*, in the unavoidable absence of Prof. Pauthenier, read a paper by the latter on the importance of electrified particles in the clearing of artificial fogs, each sweeping a path ten times its own diameter, and *Prof. Gill*, a non-meteorologist, described an experiment in which the separation of electrostatic charge on the bombardment of an ice target by water-drops was such that the target was always left negative and the drops positive. The implications of this result he left to the meteorologists.

Prof. Dobson had been anxious that as the results of so much laboratory work would be reported the study of clouds themselves would not be neglected. The balance was redressed by *Dr. Schaefer* and *Dr. Frith*, both of whom showed numerous photographs. Then *Mr. Palmer* and *Mr. Brewer* discussed splintering. *Mr. Brewer* was of the opinion that there were not enough natural nuclei to account for all the ice particles present in the atmosphere, and that in the physics of clouds splintering was thus of fundamental importance.

In the late evening *Dr. Schaefer* delighted another large audience with a "slow motion " re-showing of his photographs, and with great goodwill answered a long series of searching questions by Mr. Gold and others on his latest work in New Mexico.

There was general regret that time did not permit the subject to be further explored. It would appear that meteorologists would now do well to pause and reflect on the great body of material which has so recently been made available—little attention has, for example, been paid in this country to Russian work on atmospheric electricity[2]—and to consult with physical chemists and crystallographers on the basic problems of crystal formation[3].

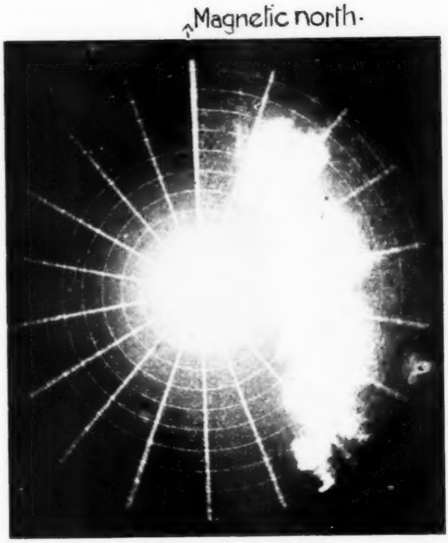
Meanwhile the publication of the papers read will be awaited with impatience.

*REFERENCES

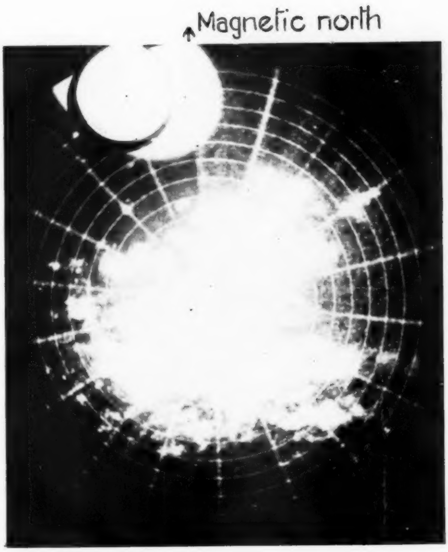
1. MOTT, N. F.; Theory of crystal growth.† *Nature, London*, **165**, 1950, p. 295.
2. FRENKEL, J.; Atmospheric electricity and lightning. *J. Franklin Inst., Philadelphia Pa.*, **243**, 1947, p. 287.
3. RIDDAL, E. K.; How crystals grow. *Nature, London*, **164**, 1949, p. 303.

†This gives the latest position of the Bristol School.

[*To face p.* 174



(*a*)

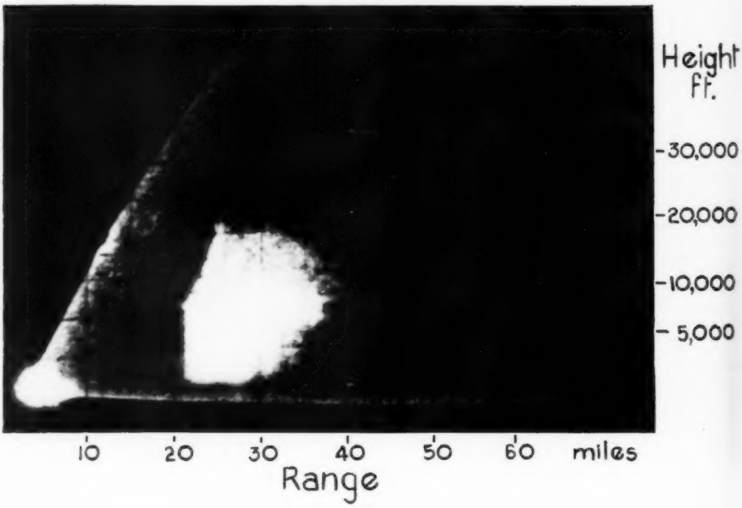


(*b*)

OCCLUSION BY RADAR

(see p. 170)

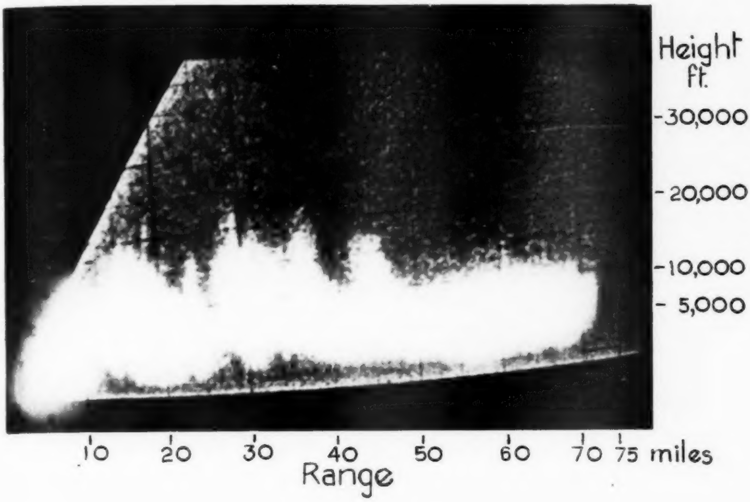
(c)



(d)

OCCLUSION BY RADAR

(see p. 170)



(*e*)

OCCLUSION BY RADAR

(see p. 170)

By courtesy of the Department of Information, Government of Australia

A. V. GOTLEY, CHIEF METEOROLOGIST AND OFFICER IN CHARGE, HEARD ISLAND, 1948

(see p. 168)

By courtesy of the Department of Information, Government of Australia

GENERAL VIEW OF CAMP AT HEARD ISLAND

By courtesy of the Department of Information, Government of Australia

CENTRAL DOME AT HEARD ISLAND

(see p. 168)

March 30, 1950: The general circulation of the atmosphere. Chairman—Mr. E. Gold.

Dr. C. G. Rossby opened the discussion after the preliminary remarks by the Chairman. He stressed the fact that, although thermal insolation is the fuel upon which the atmospheric engine feeds, for short-time forecasts we may look to the dynamical rather than the thermodynamical aspects of the problem; this view would be held suspect by Dr. Bleeker. The attempt to solve the dynamical problem consists in the construction of simple models to account for the main observed phenomena, and the gradual adjustment of these models towards complexity to account for further new information. These models would be, for example, independent of local topography and then the model adapted to account for what is observed in topographically significant areas. The choice of the fundamental assumption lies, roughly speaking, between assuming either the constancy of angular momentum or of vorticity referred to axes fixed at the earth's centre (sometimes this is referred to as absolute vorticity and the vorticity relative to the rotating earth as relative vorticity; the terminology seems unfortunate). Dr. Rossby pointed out that neither assumption seems to hold exactly and that some compromise is necessary. As an example he showed the distribution of vorticity through a region containing a jet stream; there was a maximum to the north of the jet stream, while to the south there was a rapid falling off to a small constant value. An examination of the regions of the earth in which either assumption would hold almost exclusively would be of great value. Dr. Rossby also showed some figures of experiments made by heating a rotating fluid and following the motion by means of a light powder.

Dr. S. Petterssen attacked the problem by considering whether it is possible to have a tendency towards both radiative and dynamic equilibrium, and showed that, for such equilibrium, vorticity relative to the rotating earth must increase with height in northern latitudes and decrease with height near the equator. By discussing a general vorticity theorem and applying it to polar regions, he inferred the existence of a belt of low pressure around a polar continent; this is applicable to the south-polar region but not near the north pole owing to the topography, which would cause lows over the North Pacific and North Atlantic Oceans and possibly over the Mediterranean. On applying the theorem to equatorial regions the local structure, such as the doldrums, was inferred. In middle latitudes, with neither heat sources nor sinks, the application of the theorem is more difficult but indicates a general drift northward of cyclones and southward of anticyclones over a long period of time. Dr. Petterssen showed some very interesting statistical distributions of cyclonic and anticyclonic patterns for a 40-year period which agreed with his general deductions from the vorticity theorem.

Dr. E. T. Eady considered the circulations necessary in order to account for the heat balance in the atmosphere assuming a source of heat at low levels near the equator and a sink at high levels near the pole. The simplest circulation, upflow at the equator balanced by downflow at the pole is inadmissible, and it is necessary to have dynamically unstable patterns in order to account for the flux of heat toward polar regions. These unstable patterns bear some relation to the atmospheric structures found in middle latitudes.

Dr. J. Van Mieghem dealt with the total heat balance in a thermodynamic sense, and showed that the customary neglect of certain terms, in particular those due to condensation and lateral stresses, leads to zonal circulations in

which there is a transport of heat toward the equator. Some of the common assumptions must be re-examined.

Dr. A. H. R. Goldie showed what the general circulation of the atmosphere really looks like with the aid of vertical cross-sections up to a height of 40 Km. Some of the information was obtained from calculations made on explosion sound waves. The circulations appear to be made up of cellular patterns one above the other, and Dr. Goldie pointed out that V. Bjerknes had inferred such circulations in the solar envelope but had not considered the application to the atmospheric envelope.

The discussion took place in the evening. Interesting slides were contributed by *Cdr. Rex* (United States) of " blocking " over the British Isles and by *Mr. Dwyer* (Australia) of a north-south cross-section near the east coast of Australia (prepared by Loewe) showing a strong jet stream notably nearer to the equator than those in the northern hemisphere. *Dr. Sutcliffe* remarked that a picture in which there was a single heat source and sink is a serious oversimplification. Other speakers included *Dr. Nyberg* (Sweden) and *Capt. Bundgaard* (United States).

March 30, 1950: Climatic change. Chairman—Professor Gordon Manley.

During the symposium on " Climatic change " on the afternoon of March 30, a wide range of topics was covered, from the ice ages to changes of weather in the last few years. *Prof. K. Faegri* of Norway sounded a cautionary note when he spoke of the difficulties of interpreting in terms of climate the evidence of past vegetation. The northward extension of the occurrence of a plant might mean warmer winters or warmer summers, or be the effect of some other weather element. Climatic fluctuations did not affect all areas similarly and there was a serious lag in the response of vegetation type to climate.

Prof. H. C. Willett of the Massachusetts Institute of Technology turned to more recent periods, and illustrated the temperature changes of the last hundred years from the records of a world-wide network of stations. The Arctic had warmed rapidly and the lower latitudes more slowly since about 1885. This amelioration extended southward to about latitude 40°S. The Antarctic on the other hand was getting colder. The effect was greatest in winter temperatures, and might be associated with the intensification of the continental anticyclones and their extension to the north-west. The absence of continents in the southern hemisphere accounted for the difference there.

Dr. Lysgaard of Denmark presented some data broadly confirming Prof. Willett's remarks.

Mr. C. D. Ovey of the Natural History Museum, London, returned to the study of the distant past by means of small shells taken from the sea bed. Analysis of a sample from the tropical Atlantic showed how the deeper layers contained an increasing proportion of shells of creatures which thrived in cooler water—these deposits might have been laid down in the last ice age.

Other contributors to the discussion included *Dr. Wallén* of Sweden who described changes in Swedish glaciers; *Miss N. Carruthers*, who stressed on behalf of Dr. C. E. P. Brooks the importance of the uplifting of mountains as a cause of ice ages, and *Mr. H. H. Lamb*, who drew attention to the different response of southern and northern hemispheres to increased heating of the equatorial belt. Periodicities and solar variations also received mention.

Mr. D. J. Schove presented some estimates of past climate in China and Japan based on historical records, and pointed out that the pressure and temperature rise of the last 50 years had moved slowly southward over the northern hemisphere.

Prof. G. Manley added some comments on the probable oceanic circulation during an ice age, and concluded with a plea for a search for early instrumental records which would add to our knowledge of the weather of the eighteenth century.

LETTER TO THE EDITOR

Altocumulus castellatus at Farnborough

The photograph in the centre section of the December 1949 issue of the *Meteorological Magazine* with the caption "Altocumulus castellatus at Farnborough 0840, July 13, 1945" prompts some comments which have often been in my mind. Explanations of the word "castellatus" suggest small development and small clouds as is seen by reference to standard publications such as "Cloud Forms" or "Meteorological Observer's Handbook". This idea is borne out by the famous photographs by G. A. Clarke given in these books, though measurement suggests that each example shows development through some 3,000 ft.

The picture under consideration shows an isolated cloud with a thickness of at least 5,000 ft. and a horizontal extent of at least two miles. The general characteristics of this cloud are much nearer to "cumulus" than to "altocumulus castellatus" and the fact that its base is outside the normal range associated with the term "cumulus" should surely not prevent us from using the more appropriate name. Again, codes are the servant of the observer, not his master. It would surely be more realistic and convey more information to code this as cumulus with a base in the medium range.

This type of situation is not rare. A similar one was observed at Kew at midday on November 22, 1949. There was considerable development from well above the normal convection level. To one cloud there was a mammatus base, estimated at about 8,000 ft. which persisted for some ten minutes only. Another cloud, presumably with a convection base around the same level had, from the point of view of visibility, a very much lower base and was giving light rain at the ground. These clouds must have had vertical development of the order of 10,000 ft. Add to this some low and medium layer cloud and one has a situation which is a real challenge to the observer's ingenuity.

R. H. ELDRIDGE

Kew Observatory, Richmond, Surrey, December 31, 1949

NOTES AND NEWS

"Science of Weather" Exhibition

The exhibition "The Science of Weather", presented at the Science Museum to mark the Centenary of the Royal Meteorological Society, was opened on March 27 by the Rt. Hon. Herbert Morrison, M.P., Lord President of the Council.

The Rt. Hon. G. Tomlinson, M.P., Minister of Education, took the chair and spoke of his own early interest in forecasting the weather prospects for Saturday afternoon cricket.

Sir Robert Watson-Watt, F.R.S., gave the Society's appreciation of the action of the Ministry of Education and Science Museum in arranging the exhibition. Referring to the relations between radio and meteorology, Sir Robert pointed out that, while radio was of immense value to the forecaster for the collection of observations, yet on the other hand it increased his difficulties by providing an audience of millions over a very large area for his forecasts.

Mr. H. Morrison congratulated the Society on its Centenary and spoke of the value of the exhibition in assisting the public to grasp what scientists are doing and thinking. He remarked that the aspect of meteorology in which most people were concerned was weather forecasting, and he said he would like to pay tribute to the work of the Meteorological Office whose services were relied upon by so many professions from airmen to film producers. Forecasters, he pointed out, have to publish their forecasts daily to millions, and could not, like many other scientists, keep their conclusions within a professional circle which would not let the reputation of the particular science suffer. Actually, he said, the standard of success is higher than many people think, as a recent test showed forecasts of rain in the London area were correct 9 times out of 10. The exhibition, he went on, dealt not only with forecasting but with other applications of meteorological knowledge, from bridge design to the comfort of houses, and with research. Finally, in declaring the exhibition open, he congratulated all those who had contributed to its production.

The exhibition, which will remain open until June 27, presents a unique and most comprehensive survey of meteorological methods and applications. There are five main sections:—

(*a*) historical;

(*b*) techniques of observing the weather with instruments ranging from visibility meters to "Sferic" apparatus;

(*c*) forecasting the weather, with many synoptic charts, including the historic D-day ones, and a mechanical plotting model;

(*d*) weather in our daily lives which covers applications from water supply to bridge design; and

(*e*) research, in which real "cloud seeding" on a small scale may be seen and current research charts examined.

The contributors of exhibits include the Meteorological Office, Royal Meteorological Society, the National Physical Laboratory, Building Research Station, University Meteorological Departments and several publishers and scientific instrument makers.

Hailstones encountered by aircraft near Lake Victoria, east Africa

Mr. Grinsted, Acting Director, British East African Meteorological Department, has sent a report on hail encountered by a Viking aircraft 40 miles south of Kisumu on the afternoon of April 26, 1949.

The aircraft entered a cloud described by the pilot as "murky and vaguely cumulonimbus" and encountered hail large enough to crack the $\frac{1}{2}$ to $\frac{3}{4}$ in. thick clear-vision panel and severely dent the leading edges. The aircraft was in the hail for only about 3 sec. and was afterwards in very heavy rain which penetrated the setting of the clear-vision panel and poured into the cabin. No

turbulence was encountered. On arrival at Entebbe the size of the hailstones was estimated from the dents at 2–2½ in. diameter.

Mr. Grinsted states that hail is not often reported in east Africa, but that the region of the hills to the north-east of Lake Victoria is one from which hail is most frequently reported.

New Indian Geophysical Series

The Meteorological Department of India has instituted a new quarterly periodical, the *Indian Journal of Meteorology and Geophysics*. The first number, for January 1950, was received in the Meteorological Office Library in March.

The *Memoirs* series which contains the most important of the papers produced by the Department will continue to be published, but the *Scientific Notes* and *Technical Notes* have been discontinued.

The first number of the Journal, which opens with a message from the Prime Minister of India, has 86 pages of scientific material. The longer articles are by Dr. S. K. Banerji on the foreshadowing of Indian rainfall, and by D. N. Wadia on geophysical methods in mineral exploration. There are five short articles, notes and news, reviews and letters to the editor.

Monthly climatological table for the British Commonwealth

The publication of the "Monthly climatological table for the British Commonwealth" will cease with the completion of the 1949 tables on pp. 186-7 of this issue.

It has been felt for some time that the reasons which led to the original demand for the table over 75 years ago were no longer valid, and the lack of response to the note which appeared on p. 237 of this Magazine in August 1949 confirmed this opinion.

The British Commonwealth Table has quite a long history. It originated in a request, made to G. J. Symons in 1873 by the Editor of a paper known as *The Colonies*, for the preparation of a monthly table of weather data for publication. The data were collected from the Directors of the various services, and publication began in 1874 with a table for 16 stations spread over the five continents.

Publication in *The Colonies* ceased in June 1881, but Symons, impressed with the value of the information, decided to continue its publication in his own *Symons's Meteorological Magazine*. The first tables, those for July and August 1881, appeared there in March 1882. In 1920 *Symons's Meteorological Magazine* was taken over by the Meteorological Office, and publication of the table continued without interruption. It was suspended during World War II, but was resumed with the table for January 1947 which appeared in the Magazine for July of that year.

One of the chief reasons for ceasing publication of the table now is that monthly means of pressure, temperature and rainfall for all parts of the world are available regularly in the CLIMAT messages broadcast on the 5th–7th of the months following those to which the data refer. These broadcasts, in so far as they are received at the Central Forecasting Office, Dunstable, are tabulated regularly in the Branch of the Office which deals with World Climatology. A

more complete issue in manifolded typescript is made by the United States Weather Bureau, Washington, D.C., in a series entitled *Monthly Climatic Data for the World*. These issues are available for consultation in the Meteorological Office Library at Harrow. They cover some 550 stations in both northern and southern hemispheres.

Letters advising them of the cessation of the table were sent to all services contributing data, but the Director would like to take this opportunity of expressing his thanks again to all those who have forwarded their information with such unfailing regularity in the past or who have contributed in any way towards the preparation of the table.

REVIEW

The climate of the Netherlands. Temperature, precipitation and wind. By A. Labrijn. Koninklijk Nederlandsch Meteorologisch Instituut No. 102. Mededeelingen en Verhandelingen, Serie A, No. 53. 8vo, $9\frac{1}{2}$ in.$\times 6\frac{3}{4}$ in., pp. 78. *Illus.* 's Gravenhage, 1948. 2·50 florins. Dutch with English summary.

Dr. Labrijn's work " The Climate of the Netherlands during the last two and a half centuries ", published in 1945, is well known as a mine of information for students of recent climatic variations.

In this publication, which is a supplement to the earlier one, he gives them more information in the shape of data for about a century ending in 1947 of temperature and precipitation for Utrecht, Flushing, Maastricht and Groningen (precipitation only) and frequencies of wind for Utrecht. The temperature data have been corrected and may be considered homogenous.

G. A. BULL

OBITUARIES

Hugh Robert Mill, D.Sc., LL.D.—Many of the readers of this Magazine will have learnt of the passing of Hugh Robert Mill on April 5, at the age of 88, with a sense of personal loss. From 1901 until 1919 he was Editor, maintaining publication even during the difficult war years of 1914–18. Although failing eyesight compelled him to retire in 1919 he continued unimpaired mentally. As recently as March 30 he wrote himself to the Rainfall Section of the Meteorological Office " you have given me a delightful picture of your show (of April 1) at Harrow ". A rainfall observer has paid this tribute : " I well remember the first personal letter Dr. Mill sent me, in his own handwriting, some thirty-five years ago. I always treasured that letter because it gave the measure of encouragement, which is always so very valuable at certain periods in one's life."

Dr. Mill had a full life, devoted mainly to the study of water in nature, dealing successively with oceanography, the study of lakes, the flow of rivers, the Antarctic and especially rainfall. At the University of Edinburgh he specialised in chemistry and physics, becoming chemist and physicist in 1884 to the Scottish Marine Station newly established by Mr. John Murray of the *Challenger*, at Granton on the Firth of Forth. There, in addition to marine research, he carried on a regular second order meteorological station under the supervision of Alexander Buchan and a series of experimental observations with Dr. Aitken's various patterns of thermometer screens. This work renewed his interest in geography, and he was appointed lecturer in physiography in the Heriot Watt

College, Edinburgh, where he published in 1891 a standard text-book on physical geography, appropriately entitled " The realm of nature ".

In 1892 Mill was appointed Librarian to the Royal Geographical Society, where his work included the preparation of subject and author catalogues of geographical literature and the first systematic mapping of the depths of English Lakes (published in 1895).

Following the death of G. J. Symons, F.R.S., in 1900, Mill became Director of the British Rainfall Organization and Editor of *British Rainfall* and *Symons's Meteorological Magazine* until he retired in 1919, when the Organization was incorporated in the Meteorological Office. During this period he applied his authoritative geographical knowledge, and his experience, to open up new lines of research in the study of rainfall over the British Isles. In addition to reports included in *British Rainfall* and *Symons's Meteorological Magazine* he contributed to the *Geological Survey Memoirs* chapters on the rainfall of various counties and set out the results of some of his researches in other papers, including the following:—

On the distribution of mean and extreme annual rainfall over the British Isles. *Min. Proc. Instn. Civ. Engrs., London,* **155**, Part I, 1904, p. 1.

Map studies of rainfall. *Quart. J. R. met. Soc., London,* **34**, 1908, p. 65.

Report on the rainfall in the Exe valley. *Geogr. J., London,* **34**, 1909, p. 630.

Unprecedented rainfall in East Anglia, August 25–26, 1912. *Quart. J. R. met. Soc., London,* **39**, 1913, p. 1.

Isomeric rainfall maps of the British Isles (in collaboration with Carle Salter). *Quart J. R. met. Soc., London,* **41**, 1915, p. 1.

In his enforced retirement Mill prepared " The Record of the Royal Geographical Society, 1830–1930 " on the occasion of the Society's Centenary and retained his life long interest in Antarctic exploration. In 1892 he assisted the Society in equipping for scientific work the sailing ships *Balaena* and *Active*, which set out from Dundee to explore the possibilities of whaling in the Antarctic, and in 1905 wrote " The Siege of the South Pole ". In 1923 he published " The Life of Sir Ernest Shakleton ".

Mill was Honorary Secretary of the Royal Meteorological Society from 1902 to 1906 and President in 1907 and 1908, vice-President of the Royal Geographical Society 1927–31, and President of the Geographical Association 1932. Amongst the honours and awards bestowed on him the following may be mentioned :—

1894—Makdougal Brisbane Medal of the Royal Society, Edinburgh;

1915—Victoria Research Medal of the Royal Geographical Society;

1918—Symons Memorial Medal of the Royal Meteorological Society;

1923—Gold Medal of the Royal Scottish Geographical Society;

1930—Cullum Medal of the American Geographical Society, New York;

1932—Commander Norwegian Order of St. Olav; and

1950—the newly instituted Hugh Robert Mill Medal and Prize of the Royal Meteorological Society for research in rainfall of the British Isles.

The originality of his Christmas greetings was a recurring source of pleasure to his many friends, and the last, quoted below, seems particularly appropriate as illustrating his undimmed mentality and his philosophy throughout life.

"This is the fiftieth and belike the last
Up-raising signal on our Yule-tide mast
To hail the shifting feet of friends afloat
And dip in memory of the friends who passed.

. . . .

The Sun that lavished largesse when on high
Now lurks impoverished low in Winter's sky
Withdrawn but to prepare a better Spring
And vault to Summer's height as June goes by."

Dr. Mill married first in 1889, Frances, daughter of Dr. F. B. MacDonald, Inveraray, who died in 1929, and in 1937 he married Alfreda, daughter of Frederick Dransfield, Darton, Yorkshire, and in his writings gratefully acknowledged their constant assistance.

J. GLASSPOOLE

W. J. Humphreys.—We regret to report the death of the well known American meteorologist, Professor W. J. Humphreys on November 10, 1949, at the age of 87 years. Professor Humphreys is best known to British meteorologists for his theory of the radiative equilibrium of the stratosphere, published in 1909 independently of and almost simultaneously with E. Gold's work, and for his famous book "Physics of the Air". He was distinguished in physics and astronomy as well as meteorology.

METEOROLOGICAL OFFICE NEWS

Meteorological Office, Harrow.—As part of the centenary celebrations of the Royal Meteorological Society, the Director and Lady Johnson received some 250 Fellows, including the President Sir Robert Watson-Watt, F.R.S., their guests, and overseas delegates, at the Meteorological Office, Harrow, on the afternoon of April 1, 1950.

All branches at Harrow gave exhibitions of their work and the Forecast Division showed a working forecast office and "sferics" apparatus.

During the afternoon a radio-sonde balloon was released from the roof in a somewhat boisterous wind. Some cine-photographs taken by the British Broadcasting Corporation were later broadcast on the television newsreel.

Radio-sondes are now the most important source of upper air information. There are many different types of instrument in use in different countries, and it is known that the readings are subject to errors. This can give rise to systematic discontinuities at national frontiers on the synoptic charts. Something is known about the source of these errors, but hitherto we have had no experimental data to determine their relative magnitude for different types of instruments. Thus the results of a series of comparisons of types of radio-sonde instruments in use within the European Region made recently at Payerne in Switzerland will be of special interest. These trials were organised by Dr. J. Lugeon, Director of the Swiss Meteorological Service. The British representatives at the trials were Dr. D. N. Harrison and Mr. H. E. Painter. A practically complete British radio-sonde station was taken to Payerne.

Meteorological colloquia at Dunstable.—A feature of the activities at the Central Forecasting Office is the occasional colloquium held in the Napier Shaw Laboratory. The fifth colloquium, recently held, was opened by Mr. H. H. Lamb who took as his subject " Long spells of weather in the British Isles during the past half-century ". Previous subjects have been:—

Warm-front waves and warm-occlusion secondaries.

Cyclonic development and the importance of vertical stability in the process.

Secondary depressions on cold occlusions.

Growth and decay of convection cloud.

Frost warnings.—By arrangement with the Ministry of Agriculture and Fisheries an improved system of spring frost warnings was introduced in April. These warnings give fruit-growers and market-gardeners the expected value of the night minimum air temperature on sites classified as " below average ", " average " and " above average " for their immunity from frost, depending on orographic features. The warnings are telephoned in the early afternoon from selected provincial meteorological offices to County Branch Offices of the National Farmers' Union, by whom they are disseminated to the growers.

R.A.F.V.R. Meteorological Section.—Mr. J. L. Galloway, Fighter Command, is Chief Meteorological Officer of the Section, with the rank of Squadron Leader (V.R.) He is assisted by Miss P. F. Parker (Sgt. V.R.).

Arrangements for non-continuous training and for " summer camps " for 1950 are well in hand. For a fortunate few it is possible that, if negotiations being undertaken at the time of going to press are successful, this may mean a journey to B.A.F.O. Other popular choices of areas for training are London, Cornwall, Northern Ireland and Scotland.

There are still vacancies in this Section; any who are interested are invited to apply to the Director, M.O.10.

Ocean weather ships.—A paragraph appeared in the April number about the co-operation between Netherlands' and British ocean weather ships. While on her way to Station J, which she took over for the first time, the Netherlands' O.W.S. *Cumulus* called in at Plymouth and was visited by the Marine Superintendent, Meteorological Office. He was greatly impressed by the ship and the ship's company. On the arrival of the Netherlands' ship on station J, Captain A. W. Ford, Master of O.W.S. *Weather Recorder*, accompanied by his Chief Officer, Radio Overseer and Meteorological Officer, paid her a courtesy visit.

Under the auspices of the British Ship Adoption Society three of the British ocean weather Ships have been " adopted " by schools at Glasgow.

(i) *Weather Observer* by Hillhead High School.

(ii) *Weather Recorder* by Whitehill Senior Secondary School.

(iii) *Weather Watcher* by Eastbank Senior Secondary School.

By exchange of letters and personal visits the scholars are kept in touch with the work of the ships, and they send magazines and periodicals to the ships' companies. The interest aroused amongst the scholars of Glasgow may result in some recruits for the Meteorological Office.

Sports and social activities.—In the final of the competition for the Air Ministry football cup at Northolt on April 14, the Meteorological Office, holder for the past two years, played the Directorate of Accounts. A hard game, in which defences predominated, resulted in a one-one draw, and the Bishop Shield points were shared.

In the current competition for the Bishop Shield the Office has so far gained 56 points.

The Meteorological Office Social and Sports Committee, which is responsible for general questions affecting the social interests of staff, and for organising the participation of the Office in inter-departmental competitions, has recently been reconstituted, and copies of the new rules have been circulated. An important change is the affiliation to the Committee of the Social and Sports Clubs at Dunstable and Harrow.

The Annual General Meeting of the Harrow Social and Sports Club was held on March 22, 1950, when plans for summer sports and athletics were made.

Ties in Meteorological Office colours (maroon with double narrow diagonal stripe in light blue) are now available. These ties are for sale to all members (and retired members) of the Meteorological Office, at 5*s*. each. Silk squares in the same colours, measuring 36 in. × 36 in. can be obtained at 19*s*. each. Orders, together with the necessary remittance, should be addressed to the Honorary Secretary, Meteorological Office Social and Sports Committee (Mr. H. D. Hoyle), Meteorological Office (M.O.14) Air Ministry, Kingsway, London, W.C.2.

WEATHER OF APRIL 1950

Mean pressure was above 1020 mb. around the Azores and over part of northern Canada and slightly below 1000 mb. off the west coast of Norway. It was about 5 mb. above the average for April north of the Azores. There was a large area with pressure below the average extending from Algeria northwards beyond Spitsbergen and from east Greenland south-eastwards to western Russia and Asia Minor, the deficit exceeding 10 mb. off the west coast of Norway.

In the British Isles the weather of the month was unsettled and wet, with prevailing winds from the south-west and north-west quadrants. In southern and midland districts of England it was very sunny. An unusually severe snowstorm occurred in south-east England on the night of the 25th–26th.

From the 1st–3rd a deep depression moved from the south-west of Iceland to the Baltic; winds were westerly veering to N., strong to a gale locally at exposed stations on the 1st and 2nd; showery weather prevailed, and local thunderstorms occurred on the 2nd. Long periods of bright sunshine were recorded, however, on the 2nd and 3rd. On the 4th another depression was centred off south-west Iceland, and a trough of low pressure crossed the British Isles; on the 5th and 6th a new disturbance in mid Atlantic approached our western seaboard and further troughs passed across the country. Rain or showers occurred on the 4th and scattered showers, chiefly in the west and north, on the 5th and 6th. In the south, conditions on the 6th and 7th were affected by a continental anticyclone and rather warm, fair weather prevailed. From the 7th–9th a depression over mid Atlantic moved east-north-east to the neighbourhood of Thorshavn and then turned north, and on the 10th a

secondary depression moved rapidly east across north Ireland and north England. Rain fell in western and northern districts on the 7th and showers occurred generally from the 8th–11th. Gales were recorded locally on the 8th and 9th and were wide-spread and severe in places on the 10th; gusts of 94 m.p.h. and 92 m.p.h. were registered respectively at Liverpool and Squires Gate. Subsequently, in the rear of depressions over the North Sea, a spell of cool north-westerly winds occurred, with showers of rain, hail, sleet and local thunder but long periods of bright sunshine. On the 15th a wedge of high pressure moved south-east across the British Isles and low screen minimum temperatures were registered locally on the mornings of the 15th and 16th (22°F. at Eskdalemuir on the 15th and 23°F. at Eskdalemuir and 26°F. at Elmdon on the 16th). On the 17th a depression off south-west Ireland moved to France; rainfall was general and rather heavy locally in England. On the 19th and 20th another ridge moved south-east over the country followed by a weak trough. Fair weather prevailed in most parts on the 19th but some rain, mostly slight, occurred in the west and north on the 20th. Thereafter the Azores anticyclone spread north-east giving another fair day. The period 19th–22nd was among the warmest spells of the month; day temperatures exceeded 60°F. locally, particularly on the 20th and 21st. On the 22nd a small depression developed off north-west Ireland and moved south-east, giving rain generally on the 22nd and 23rd. Meanwhile, a depression east of Greenland moved south-east to the southern North Sea. In the rear of this disturbance an arctic air stream, with strong gusty winds, covered the British Isles; temperature fell rapidly and sleet and snow showers occurred. By 1800 G.M.T. on the 25th a secondary polar depression was situated over the Bristol Channel, and subsequently it moved along the English Channel, being centred over the Straits of Dover by 0600 G.M.T. on the 26th. Unusually heavy snowfall occurred in south-east England; on the morning of the 26th level snow lay 6 in. deep or more in a narrow belt from Throwley, 4 miles south-west of Faversham in Kent, to Upavon and Everleigh on the Wiltshire Downs. Much damage occurred to trees, shrubs, telegraph poles, etc. Low screen minima included 21°F. at Newton Rigg and 22°F. at Eskdalemuir on the 25th and 25°F. at Elmdon and Wittering on the 26th. On the closing days of the month a trough of low pressure associated with an Atlantic depression moved slowly north-east across the British Isles causing rain generally and a considerable rise in temperature; a maximum of 64°F. was registered at Mildenhall on the 30th.

The general character of the weather is shown by the following provisional figures :—

	Air Temperature			Rainfall		Sunshine
—	Highest	Lowest	Difference from average daily mean	Percentage of average	No. of days difference from average	Percentage of average
	°F.	°F.	°F.	%		%
England and Wales ..	68	21	+0·1	135	+5	105
Scotland	62	17	−0·7	150	+5	99
Northern Ireland ..	64	25	−0·4	189	+8	80

CLIMATOLOGICAL TABLE FOR THE BRITISH COMMONWEALTH, DECEMBER 1949

Stations	Pressure: Mean of day M.S.L.	Pressure: Diff. from normal	Temperatures: Absolute Max.	Temperatures: Absolute Min.	Temperatures: Mean values Max.	Temperatures: Mean values Min.	Temperatures: Mean values ½ Max. and Min.	Temperatures: Mean values Diff. from normal	Temperatures: Mean values Wet bulb	Relative humidity	Mean cloud amount	Precipitation: Total	Precipitation: Diff. from normal	Precipitation: Days	Bright Sunshine: Daily mean	Bright Sunshine: Percentage of possible
	mb.	mb.	°F.	°F.	°F.	°F.	°F.	°F.	°F.	%	oktas	in.	in.		hr.	%
London, Kew Observatory	1013·2	+0·6	55	30	48·0	39·2	43·6	+2·1	41·3	87	5·5	1·47	−0·82	17	1·6	20
Gibraltar	1018·0	−2·3	70	36	61·9	53·2	57·5	+1·5	53·6	85	5·7	9·36	—	14	3·8	39
Malta	1018·1	+1·9	71	44	63·4	52·8	58·1	+0·2	56·0	72	4·9	0·96	—	10	6·2	64
St. Helena	1013·9	−1·9	72	54	67·7	57·1	62·4	+1·5	57·4	95	7·8	0·74	−1·08	8	—	—
Lungi, Sierra Leone	1010·5	—	90	69	85·9	72·6	79·3	—	74·5	92	3·5	1·06	—	6	7·4	—
Lagos, Nigeria ..	1009·3	−1·2	92	66	90·6	69·7	80·1	−1·7	76·8	91	6·1	0·00	—	0	7·0	60
Kaduna, Nigeria ..	1010·2	—	92	52	88·6	55·5	72·1	−2·2	53·7	14	0·5	0·00	0·00	0	10·4	91
Chileka, Nyasaland	1011·6	−1·0	95	60	85·3	68·4	76·9	+0·8	69·5	73	5·4	6·77	+1·05	15	6·2	48
Lusaka, Rhodesia ..	1010·6	−0·8	88	61	79·8	63·4	71·6	−0·2	65·3	85	6·5	9·07	+2·63	25	5·1	39
Salisbury, Rhodesia	1010·6	−1·2	85	55	78·9	60·7	69·8	+0·4	62·8	72	5·5	5·70	−1·40	15	5·8	44
Cape Town	1013·5	−0·8	88	47	76·7	60·3	68·5	+0·6	58·0	57	2·1	0·42	−0·39	5	—	—
Palmietfontein, S. Africa	1009·9	—	87	47	78·9	56·8	67·9	—	60·5	69	4·0	7·32	—	16	9·0	—
Mauritius	1014·3	+0·6	93	64	88·0	69·8	78·9	+0·6	69·3	60	4·2	1·28	−3·40	16	9·5	71
Calcutta, Alipore Obsy.	1014·3	−1·3	87	49	79·7	53·9	66·8	+0·3	57·8	66	0·3	0·00	−0·24	0	9·3	86
Bombay	1012·3	−1·2	92	63	86·8	67·2	77·0	−0·4	66·6	68	0·2	0·00	−0·05	0	10·3	95
Madras	1013·2	−0·3	85	62	83·6	67·4	75·5	−1·2	69·4	78	3·8	0·04	−5·31	1	9·5	84
Colombo, Ceylon ..	1010·1	−0·2	89	66	85·4	72·0	78·7	−0·8	72·8	85	5·3	3·35	−1·77	6	5·7	49
Singapore	1008·1	−1·6	91	72	86·0	73·7	79·9	0·0	75·4	85	6·2	12·56	+2·00	26	3·8	32
Hongkong	1016·9	−2·8	80	56	69·1	61·7	65·4	+2·4	60·9	78	—	0·40	−0·63	11	3·4	32
Sydney, N.S.W. ..	1010·4	−1·5	98	56	76·8	62·6	69·7	−0·4	63·9	69	5·2	1·84	−1·02	8	7·3	51
Melbourne	1012·2	−0·5	91	46	71·3	52·4	61·9	−2·9	54·3	59	4·8	1·24	−1·03	9	7·2	49
Adelaide	1013·0	−0·3	100	49	79·2	56·5	67·9	−3·2	57·3	43	4·0	0·20	−0·83	4	8·6	60
Perth, W. Australia	1011·6	−1·6	105	56	83·2	61·7	72·5	+1·7	63·8	54	1·0	0·00	−0·56	0	10·3	72
Coolgardie	1010·9	−0·3	109	48	90·4	61·8	76·1	+0·4	59·8	37	2·9	0·51	−0·18	3	—	—
Brisbane	1012·1	+0·1	95	61	83·6	66·5	75·1	−1·3	67·9	68	3·3	3·48	−1·41	4	10·3	75
Hobart, Tasmania	1007·0	−2·7	89	38	65·3	48·6	56·9	−3·3	49·7	52	5·7	1·46	−0·53	13	7·1	46
Wellington, N.Z. ..	1007·5	−4·7	72	44	64·7	52·4	58·5	−0·5	55·3	74	5·8	3·92	+0·70	13	8·1	54
Suva, Fiji	1007·3	−1·3	90	71	84·4	74·2	79·3	+0·3	75·4	86	6·5	15·00	+2·48	24	4·9	37
Apia, Samoa ..	1007·5	−0·4	88	72	85·5	73·4	79·5	−0·5	76·7	81	6·1	26·46	+12·44	26	4·1	32
Kingston, Jamaica	1013·3	−0·7	91	65	86·8	69·5	78·1	+0·4	71·5	80	2·4	1·42	−0·17	6	8·4	76
Grenada, W. Indies																
Toronto	1022·9	+5·3	57	13	37·7	27·0	32·3	+5·2	28·3	78	7·9	3·05	+0·58	14	3·3	37
Winnipeg	1019·8	+1·1	37	−25	10·4	−2·8	3·8	−2·0	2·4	—	5·9	1·61	+0·67	12	3·5	43
St. John, N.B. ..	1021·2	+7·2	52	4	37·0	22·5	29·7	+5·3	27·5	89	6·5	6·33	+2·16	12	3·6	41
Victoria, B.C. ..	1014·2	−2·5	53	18	42·1	31·0	36·5	−4·6	34·3	89	8·1	8·22	+2·48	25	1·7	20

CLIMATOLOGICAL TABLE FOR THE BRITISH COMMONWEALTH, YEAR 1949

Stations	Pressure		Temperatures							Relative humidity	Mean cloud amount	Precipitation			Bright Sunshine	
	Mean of day M.S.L.	Diff. from normal	Absolute		Mean values							Total	Diff. from normal	Days	Daily mean	Percentage of possible
			Max.	Min.	Max.	Min.	½ Max. and Min.	Diff. from normal	Wet bulb							
	mb.	mb.	°F.	°F.	°F.	°F.	°F.	°F.	°F.	%	oktas	in.	in.		hr.	%
London, Kew Observatory	1018·2	+3·3	86	23	59·6	45·5	52·5	+2·1	48·2	78	5·5	19·10	−4·70	125	4·9	40
Gibraltar	1018·2	+0·3	99	36	72·3	60·2	66·3	+2·1	61·1	77	4·1	31·53	—	77	7·7	64
Malta	1017·3	+1·9	94	36	71·3	59·0	65·1	−1·0	61·6	68	3·5	20·29	—	86	8·9	74
St. Helena	1016·1	−1·0	82	51	68·2	57·9	63·1	+2·1	58·3	96	7·3	33·06	+1·42	185	—	—
Lungi, Sierra Leone	1012·0	—	94	63	86·1	73·4	79·7	—	74·4	87	5·2	122·13	—	154	—	—
Lagos, Nigeria ..	1011·1	+0·2	97	64	88·7	71·3	80·0	−0·7	76·6	84	6·5	56·02	—	129	5·3	44
Kaduna, Nigeria ..	1009·3	—	100	52	88·2	65·2	76·7	−0·5	65·9	55	4·7	37·16	−16·67	95	7·7	64
Chileka, Nyasaland	1016·3	−0·3	98	51	83·3	63·9	73·7	+1·6	63·8	64	3·3	17·44	−18·64	70	7·4	61
Lusaka, Rhodesia ..	1013·9	−0·1	101	44	82·9	59·2	71·1	+2·1	60·0	65	3·3	23·38	−13·89	80	8·5	71
Salisbury, Rhodesia	1015·9	−0·3	94	37	77·9	54·5	66·2	+1·0	56·5	62	2·8	22·53	−10·91	69	8·0	66
Cape Town	1016·8	−0·2	102	38	72·7	54·8	63·7	+1·4	53·5	66	3·5	25·95	+0·91	120	—	
Palmietfontein, S. Africa	—	—	94	20	74·3	47·7	61·0	—	50·6	66	2·7	31·11	—	89	9·0	—
Mauritius	1015·9	−0·2	93	53	82·1	67·5	74·8	+0·8	67·8	69	4·4	38·95	−10·80	212	7·8	64
Calcutta, Alipore Obsy.	1007·3	−0·3	102	49	88·6	71·1	79·9	+1·1	72·8	76	3·5	65·02	+0·70	126	7·5	62
Bombay	1008·3	−0·9	101	59	87·9	74·5	81·2	+0·6	73·7	77	3·4	108·51	+36·32	124	7·3	60
Madras	1008·6	−0·2	108	62	90·8	74·7	82·7	−0·4	74·1	75	4·6	38·21	−11·35	84	8·3	69
Colombo, Ceylon ..	1009·9	+0·2	93	61	86·4	74·8	80·6	−0·4	74·8	83	5·1	96·26	+16·13	172	7·0	58
Singapore	1009·5	0·0	94	71	87·5	75·3	81·4	+0·5	76·3	81	5·8	84·26	−10·86	185	—	—
Hongkong	1012·8	+0·3	92	43	78·1	69·1	73·6	+1·3	68·7	80	—	82·74	−2·99	144	5·2	43
Sydney, N.S.W. ..	1016·5	+0·6	98	39	70·4	56·2	63·3	+0·2	57·7	73	4·6	66·26	+18·78	150	6·5	54
Melbourne	—	—	100	32	65·5	48·6	57·1	−1·3	51·4	69	5·5	31·41	+5·94	163	5·2	43
Adelaide	1017·9	+0·8	100	37	69·5	51·6	60·5	−2·5	—	—	4·6	18·23	−2·92	118	6·3	52
Perth, W. Australia	—	—	105	39	75·7	56·1	65·9	+1·7	58·8	61	3·6	27·15	−7·22	127	7·6	63
Coolgardie																
Brisbane	1016·4	+0·5	95	39	76·7	59·7	68·2	−0·7	61·5	66	3·9	47·18	+1·89	121	7·8	65
Hobart, Tasmania																
Wellington, N.Z. ..	1013·4	−0·8	77	35	59·9	48·2	54·1	+0·1	51·2	79	5·5	43·21	−4·83	158	5·8	48
Suva, Fiji	1011·5	+0·2	93	63	82·0	72·0	77·0	0·0	73·5	84	6·1	179·54	+62·40	269	4·9	40
Apia, Samoa ..	1010·5	+0·5	90	66	86·3	73·7	80·0	+0·5	76·8	80	5·0	117·66	+5·66	238	7·3	61
Kingston, Jamaica	1014·1	+0·4	94	65	88·1	71·9	80·0	+0·7	73·3	74	2·9	24·50	−9·09	69	8·2	68
Grenada, W. Indies																
Toronto	1017·0	+0·4	99	4	57·8	41·9	49·9	+4·7	42·2	76	5·9	24·84	−6·45	119	5·9	48
Winnipeg	1015·6	−0·6	105	−43	46·1	26·3	36·2	+1·6	28·8	—	5·5	22·96	+2·78	118	5·9	48
St. John, N.B. ..	1015·9	+1·3	87	−6	51·7	36·5	44·1	+2·9	39·3	83	6·5	52·21	+4·13	163	5·4	44
Victoria, B.C. ..	1017·2	+0·5	84	12	56·2	40·1	48·1	−1·3	42·1	88	5·7	35·46	+5·15	151	6·1	50

RAINFALL OF APRIL 1950

Great Britain and Northern Ireland

County	Station	In.	Per cent. of Av.	County	Station	In.	Per cent. of Av.
London	Camden Square ..	2·12	138	*Glam.*	Cardiff, Penylan ..	2·68	107
Kent	Folkestone, Cherry Gdn.	2·85	172	*Pemb.*	St. Ann's Head ..	1·82	89
,,	Edenbridge, Falconhurst	3·31	189	*Card.*	Aberystwyth	2·90	141
Sussex	Compton, Compton Ho.	2·88	144	*Radnor*	Tyrmynydd	5·11	139
,,	Worthing, Beach Ho.Pk.	1·94	124	*Mont.*	Lake Vyrnwy	6·47	204
Hants	Ventnor, Roy. Nat. Hos.	2·03	121	*Mer.*	Blaenau Festiniog ..	11·26	182
,,	Bournemouth			*Carn.*	Llandudno	2·31	137
,,	Sherborne St. John ..	2·56	145	*Angl.*	Llanerchymedd ..	3·11	141
Herts.	Royston, Therfield Rec.	1·78	113	*I. Man.*	Douglas, Borough Cem.	4·34	178
Bucks.	Slough, Upton	2·23	156	*Wigtown*	Port William, Monreith	2·83	129
Oxford	Oxford, Radcliffe ..	2·14	134	*Dumf.*	Dumfries, Crichton R.I.	3·36	142
N'hant.	Wellingboro', Swanspool	1·91	128	,,	Eskdalemuir Obsy. ..	6·18	182
Essex	Shoeburyness	1·43	118	*Roxb.*	Kelso, Floors	1·71	109
Suffolk	Campsea Ashe, High Ho.	2·62	146	*Peebles*	Stobo Castle	3·57	171
,,	Lowestoft Sec. School ..	2·03	137	*Berwick*	Marchmont House ..	2·55	126
,,	Bury St. Ed., Westley H.	1·86	122	*E. Loth.*	North Berwick Res. ..	1·57	112
Norfolk	Sandringham Ho. Gdns.	2·26	149	*Midl'n.*	Edinburgh, Blackf'd. H.	1·98	135
Wilts.	Bishops Cannings ..	2·51	124	*Lanark*	Hamilton W. W., T'nhill	3·80	203
Dorset	Creech Grange.. ..	2·78	129	*Ayr*	Colmonell, Knockdolian	3·21	127
,,	Beaminster, East St. ..	2·81	119	,,	Glen Afton, Ayr San ..	4·53	151
Devon	Teignmouth, Den Gdns.	1·61	80	*Bute*	Rothesay, Ardencraig	4·04	136
,,	Cullompton	2·76	122	*Argyll*	L. Sunart, Glenborrodale	6·63	159
,,	Ilfracombe	2·35	112	,,	Poltalloch	3·87	128
,,	Okehampton, Uplands	3·64	114	,,	Inveraray Castle ..	6·95	151
Cornwall	Bude, School House ..	2·31	122	,,	Islay, Eallabus ..		
,,	Penzance, Morrab Gdns.	2·39	98	,,	Tiree	3·42	139
,,	St. Austell	2·99	106	*Kinross*	Loch Leven Sluice ..	2·59	135
,,	Scilly, Tresco Abbey ..	1·19	61	*Fife*	Leuchars Airfield ..	1·24	78
Glos.	Cirencester	2·67	143	*Perth*	Loch Dhu	5·41	114
Salop.	Church Stretton ..	2·63	121	,,	Crieff, Strathearn Hyd.	2·48	113
,,	Cheswardine Hall ..	3·29	188	,,	Pitlochry, Fincastle ..	2·70	121
Worcs.	Malvern, Free Library	2·00	111	*Angus*	Montrose, Sunnyside ..	1·27	70
Warwick	Birmingham, Edgbaston	1·96	113	*Aberd.*	Braemar	4·11	173
Leics.	Thornton Reservoir ..	1·65	97	,,	Dyce, Craibstone ..	1·90	92
Lincs.	Boston, Skirbeck ..	1·77	131	,,	Fyvie Castle	2·18	102
,,	Skegness, Marine Gdns.	2·38	178	*Moray*	Gordon Castle	2·74	157
Notts.	Mansfield, Carr Bank ..	2·35	136	*Nairn*	Nairn, Achareidh ..	2·67	191
Derby	Buxton, Terrace Slopes	4·83	164	*Inverness*	Loch Ness, Garthbeg ..	5·03	221
Ches.	Bidston Observatory ..	2·80	172	,,	Glenquoich	11·05	170
Lancs.	Manchester, Whit. Park	3·12	163	,,	Fort William, Teviot ..	7·47	166
,,	Stonyhurst College ..	3·93	145	,,	Skye, Duntuilm ..	4·57	141
,,	Blackpool			*R. & C.*	Tain, Tarlogie House ..	2·92	160
Yorks.	Wakefield, Clarence Pk.	2·61	155	,,	Inverbroom, Glackour..	8·71	234
,,	Hull, Pearson Park ..	2·49	160	,,	Applecross Gardens ..	6·12	179
,,	Felixkirk, Mt. St. John	1·91	114	,,	Achnashellach	11·15	208
,,	York Museum	2·64	165	,,	Stornoway Airfield ..	4·87	169
,,	Scarborough	2·51	161	*Suth.*	Loch More, Achfary ..	12·85	265
,,	Middlesbrough.. ..	1·88	137	*Caith.*	Wick Airfield	2·44	123
,,	Baldersdale, Hury Res.	2·91	120	*Shetland*	Lerwick Observatory ..	2·71	118
Norl'd.	Newcastle, Leazes Pk. ..	1·95	123	*Ferm.*	Crom Castle	4·80	188
,,	Bellingham, High Green	2·47	114	*Armagh*	Armagh Observatory ..	4·05	193
,,	Lilburn Tower Gdns. ..	2·21	112	*Down*	Seaforde	3·58	137
Cumb.	Geltsdale	2·65	124	*Antrim*	Aldergrove Airfield ..	3·68	175
,,	Keswick, High Hill ..	4·70	153	,,	Ballymena, Harryville..	4·90	186
,,	Ravenglass, The Grove	3·33	134	*L'derry*	Garvagh, Moneydig ..	5·68	233
Mon.	Abergavenny, Larchfield	2·17	86	,,	Londonderry, Creggan	5·75	224
Glam.	Ystalyfera, Wern House	5·63	148	*Tyrone*	Omagh, Edenfel ..	4·69	178